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Profile Survey of the Sandy River for Marmot Dam Removal

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Profile Survey of the Sandy River for Marmot Dam Removal

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Introduction

Marmot Dam, located on the Sandy River near Portland, Oregon (**Error! Reference source not found.**) was removed in October 2007 to restore fish passage into the upstream watershed. Marmot Dam was a 14-m (40-foot) high concrete structure located approximately 30 river miles upstream from the confluence of the Sandy River with the Columbia River. The upstream reservoir had filled with sediment, which will now be eroded and transported downstream by the river during subsequent high flows. Previous sediment studies have evaluated the potential impacts to hydraulic and sediment processes of the Sandy River due to dam removal (Stillwater Sciences, 2000).

Scientists involved in the dam removal identified a need to complete a continuous longitudinal profile of the Sandy River prior to dam removal in order to evaluate the effects of dam removal with more certainty. Topographic monitoring efforts for the dam removal include detailed cross section data collection in the reservoir and in some downstream river channel areas. A longitudinal profile of water surface elevation downstream of the dam was collected in 2004 during low flow to document baseline channel slopes. However, channel bed elevation data were not collected during this effort; furthermore, a large flood occurred in 2006 that was observed by locals to have filled in many of the pools that previously existed. In September 2007 and June 2009, the Sedimentation and River Hydraulics Group was funded through the Science and Technology branch of the Bureau of Reclamation (Grant #6284) to conduct a longitudinal profile of the Sandy River before and after the removal of Marmot Dam. This survey data can be used to evaluate predictions in sediment transport and monitor changes in river morphology after the dam is removed.

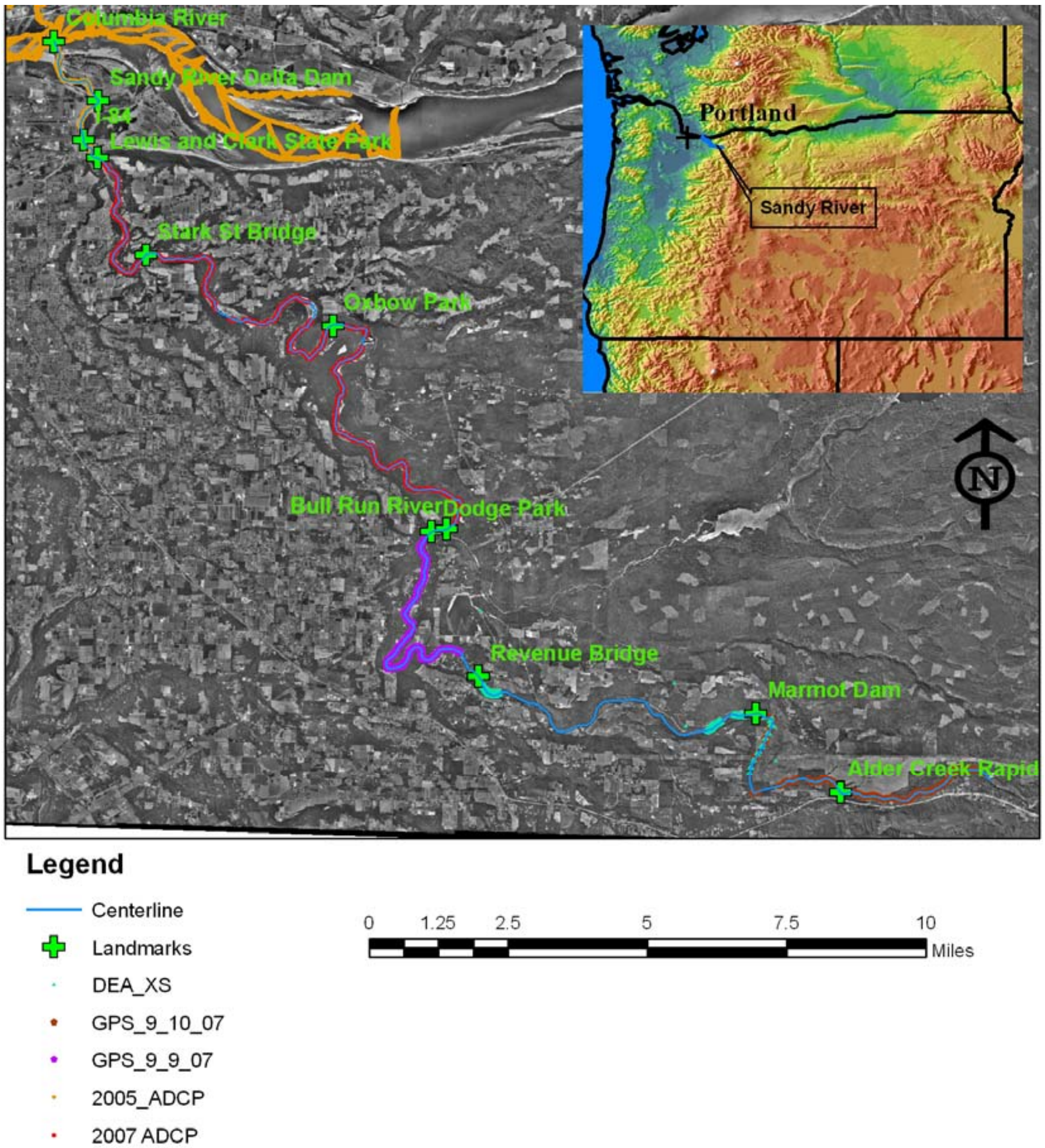

Figure 1: Aerial view of the study area and survey data collected by date.

Site Description

The Sandy River is located a short distance east of Portland, OR. The river begins on Mt. Hood and drains into the Columbia River near Troutdale, OR. Many of the river reaches flow through deep canyons with limited access. The underlying geology is volcanically derived and past pyroclastic flows and lahars have filled the lower valley with as much as 20-m of sediment (Allen, 1988). For purposes of discussion, the following reaches are defined based on available boat access:

1. Brightwood to Marmot Dam (surveyed 2007 and 2009)

2. Marmot Dam to Revenue Bridge (not surveyed)
3. Revenue Bridge to Dodge Park (surveyed 2007 and 2009)
4. Dodge Park to Oxbox Park (surveyed 2009 and 2009)
5. Oxbow Park to Lewis and Clark State Park (surveyed 2007)
6. Lewis and Clark State Park to confluence with Columbia (surveyed 2005)

Qualitative observations on sediment sizes present in the bed and bars during the 2007 survey are provided for each reach. In the upstream-most reach (Brightwood to Marmot Dam), the rapids are generally formed by large boulders and cobbles and small boulders were observed on the channel bed and surface of bars. One large rapid, Alder Creek Rapid, is formed by bedrock. In the area upstream from Marmot Dam, which is influenced by the reservoir pool, there are very few large boulders present on bar surfaces. Riffles are composed primarily of cobbles and small boulders.

From Revenue Bridge to Dodge Park the rapids contain large boulders and localized bedrock, particularly near Revenue Bridge. The bed is armored with small boulders and cobbles. Much of this reach is laterally confined by bedrock or high terraces.

From Dodge Park to Oxbow Park the rapids contain large boulders and bedrock while the bed is composed of small boulders and cobbles. Near the downstream end of this reach the rapids give way to riffles formed from cobbles and small boulders. The bed material also changes to cobbles and gravel. Another change in this reach is the presence of tall sand banks. In these areas the pools are filled with sand and dunes can be seen in the channel.

From Oxbow Park to Lewis and Clark State Park the riffles contain small boulders and cobbles. The pools in this reach were often filled with sand, but most of the bar surfaces appeared to be composed of gravel and cobble. While this reach was often confined by bedrock walls, there were many tall sand banks that often corresponded to areas with filled pools.

River Discharge

The hydrology of the Sandy River is generally characterized by low flows in late summer, high flows generated from rainfall and rain-on-snow in winter, and spring snowmelt as seen in Figure 2 (Sitllwater Sciences, 2000). The peak of record for the Sandy River occurred in December 1964 (Figure 3) during a storm that affected much of the Pacific Northwest. More recently, a park ranger at Oxbow Park noted that locals observed bank erosion in the lower Sandy River (Oxbow Park to Lewis and Clark State Park) that is believed to have occurred during the November 2006 flood. The published peak discharge for this flood downstream from the Bull Run River was 41,200 ft^3/s. Gage flows during the 2007 river survey were between 200 and 400 ft^3/s and 1,000 and 1,080 ft^3/s during the 2009 survey.

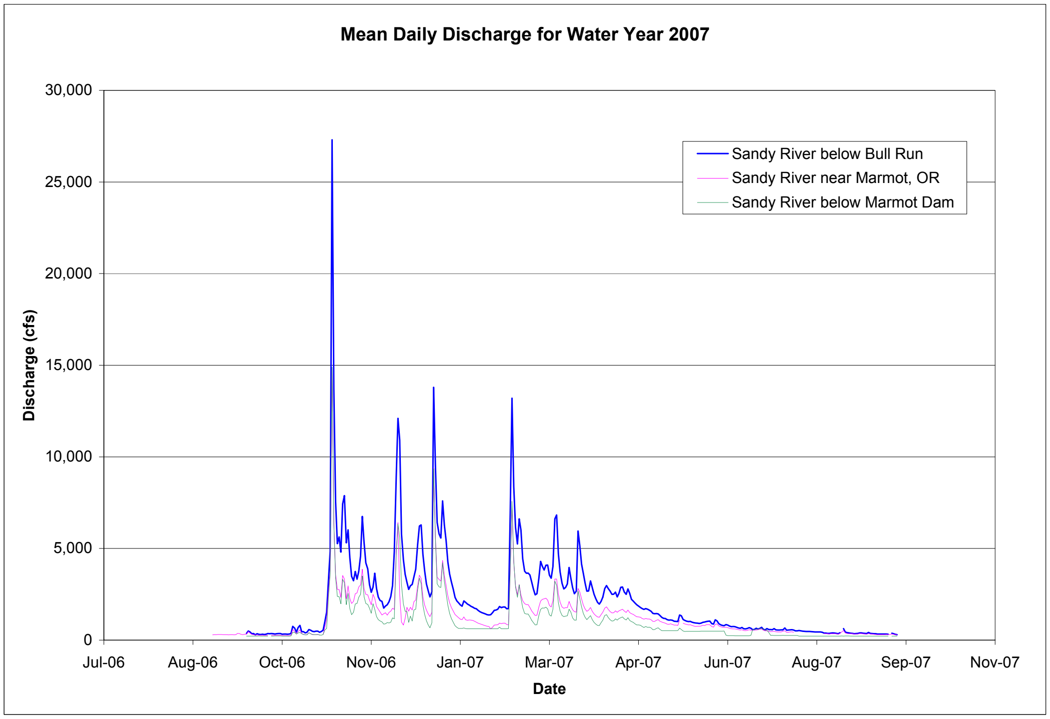

Figure 2 Mean daily flow record for water year 2007.

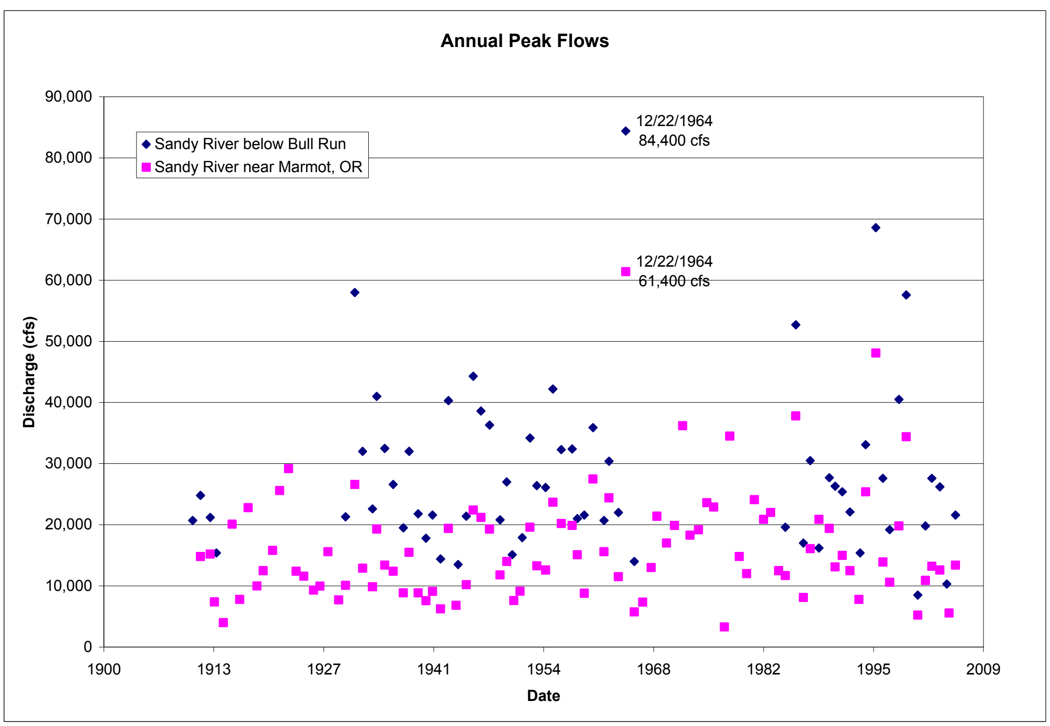

Figure 3 Peak flows for the Sandy River.

Data Collection Methods

The bathymetric survey data for this project were collected using a Teledyne RD Instruments 1200 kHz Workhorse Rio Grande Acoustic Doppler Current Profiler (ADCP). Accurate position and water surface elevations were achieved by linking the ADCP to a Trimble 5800 GPS system operating with a Real Time Kinematic (RTK) survey.

During the 2007 survey the ADCP was used to measure the water depth for the Dodge Park to Lewis and Clark reaches. The ADCP was damaged during the survey, and was not available for the remaining reaches between Brightwood and Marmot Dam, and Revenue Bridge to Dodge Park. The survey equipment was mounted on a raft (Figure 4) and connected to a field computer which processes information from both instruments. The GPS unit on the raft was mounted above the ADCP and was set to export the GGA NMEA data string. This data string exports the GPS position data directly to the computer. The computer program WinRiver (Version 1.06, RD Instruments, San Diego, CA) reads the GGA data string and uses it to determine the position of the ADCP. The ADCP was set to a depth of 0.6 feet, the magnetic variation was set to 16.4 degrees, the bottom type was set to cobble, and water mode 12sb and bottom mode 7 were used. A compass calibration was performed each day the ADCP was used. During the boat surveys GPS observations were taken to measure the water surface elevation approximately every 25 feet. These measurements were later used to compute the water surface elevation of the ADCP depth measurements. Where logistically possible, more frequently spaced GPS points were collected in riffles and rapids.

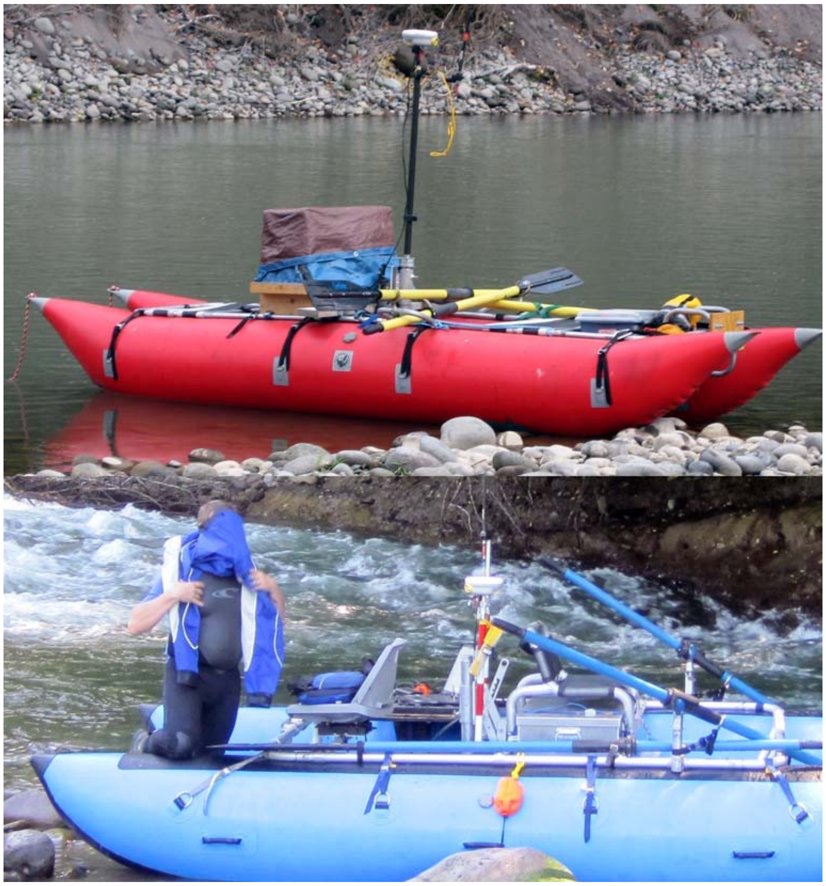

Figure 4: The ADCP, GPS, and field computer mounted on survey rafts.

Prior to the 2007 and 2009 profile surveys, control points were established along the river for use in a GPS control network. A published National Geodetic Survey (NGS) control point (AJ8177 near Sandy, OR) was used as the starting point for the control network. To establish the control network, a GPS base station was set at this location. Using an RTK survey, several points were set that could be used as base locations during the profile survey. The practical range for a RTK survey from each base location is about 5 to 8 miles depending on site conditions. Since the total reach being surveyed was over 35 miles, several base setups were needed. Additional points were set by "leap-frogging" from the known NGS point to the new control points. Survey errors can be easily propagated with this method, so additional post-processing was needed to refine the coordinates of the control network points. During the profile survey, the base stations would run for over 6 hours a day and the GPS receivers were set to collect position data at a specified interval. These data were later submitted to OPUS (http://www.ngs.noaa.gov/OPUS/) to more accurately determine the location of the control points. Elevations are derived from GEOID 03.

Data Processing

Water surface elevation data collected on the boat and logged data collected at the base stations are downloaded to Trimble Geomatics Office (TGO version 1.62). Data logged at the base stations were submitted to OPUS for further post processing. The control point coordinates were adjusted based on these results. After these adjustments were made, the water surface observations were exported in shapefile format for use in Arcmap (Version 9.X, ESRI, Redlands, CA).

The ADCP data require several processing steps. First, the ADCP raw data files are exported in ASCII format using WinRiver (playback mode). The second step in processing is to use AdMap (Dave Mueller, USGS version 1.4, 2007) to export bathymetry. AdMap can export several types of velocity and bathymetry data but for the purposes of this project only the position and depth for each of the four ADCP beams (multibeam bathymetry) were exported. Beam depths are obtained by creating a water surface file within AdMap in which the water surface elevation for each transect is set to zero. Coordinates for each of the transducer depth measurements are calculated by applying corrections for pitch and roll, compass heading, and beam angle. The AdMap processed files are exported in text file format and include position data in UTM coordinates. With a small amount of manipulation these files can be imported into ArcMap for further processing.

Once the ADCP multibeam bathymetry data and the GPS water surface elevation data are in ArcMap, bed elevations for the ADCP measurements can be determined. The GPS water surface elevations are used to create a water surface TIN (Triangulated Irregular Network). Using the "convert feature to 3D" tool in 3D analyst, the ADCP multibeam bathymetry points are assigned an elevation based on its position relative to the water surface TIN. Once this process has been completed, fields for water surface elevation and bed elevation can be created and populated in the attribute table of the new 3D feature class.

River stations were assigned to the survey data using the Linear Referencing Tools in ArcMap. First a somewhat arbitrary river centerline is drawn. This line will serve as the base for all stationing. Once this line is drawn it, is converted to a route and the "locate features along routes" tool is used to station the survey data based on their relative location along the route.

Profile Results

The September 2007 Sandy River profile extends from the Lewis and Clark Park upstream to the Brightwood Bridge, but does not include the 7 mile stretch downstream from Marmot Dam (Sandy Gorge), which is a Class IV whitewater canyon. A previous Reclamation survey was completed in 2005 from Lewis and

Clark Park downstream to the Columbia River. The 2009 survey repeated three reaches (Brightwood to Marmot Dam, Revenue Bridge to Dodge Park, and Dodge Park to Oxbow Park) surveyed in 2007. GPS coverage was limited in many areas due to poor satellite geometry caused by tight canyon conditions in most of the reach. The GPS coverage during the 2007 survey provided a relatively continuous profile with minor gaps except for the reach upstream from Marmot Dam where the river alignment and high valley walls led to very poor GPS reception. In 2009 the GPS reception was marginal and there were many large gaps without GPS water surface measurements. Due to time and budget constraints the reach from Lewis and Clark Park to the Columbia River was not resurveyed in 2007 or 2009. Data from the 2005 survey was used for this portion of the profile (Reclamation, 2006).

Pre-dam Removal

After the ADCP was damaged during the 2007 survey an off the shelf fish finder was used to used to measure depth in the remaining reaches. A depth was manually recorded for specific GPS observations. Unfortunately, the depth sounder was particularly sensitive to entrained air and would not work through the rapids and often had difficulty in the upper end of the pools. Figure 5 shows the profile of the Sandy River from Brightwood to the Columbia River not including the 2009 survey data. The plot contains data from several sources including PGE, Gregg Stewart, and Reclamation.

There are some interesting trends in the water surface profiles from 2004 (Stewart, 2006) and 2007 upstream from Oxbow Park. Upstream from Oxbow Park, the two profiles are very similar and plot nearly on top of each other. This indicates that the rapids were not significantly changed by the high flows in November 2006. Conversely, downstream from Oxbow Park there are significant difference between the two profiles. In this reach the riffle crests are nearly identical but the water profiles through the pools are very different. In the 2004 survey the pools were very flat and the profile has a stepped appearance. In the 2007 survey the pools are much steeper. During the 2007 survey many of the pools in this reach were very shallow and filled with sand. It is possible that the higher water surface slope through this reach in 2007 is the result of sand deposition in the pools that has resulted in increased water surface elevations.

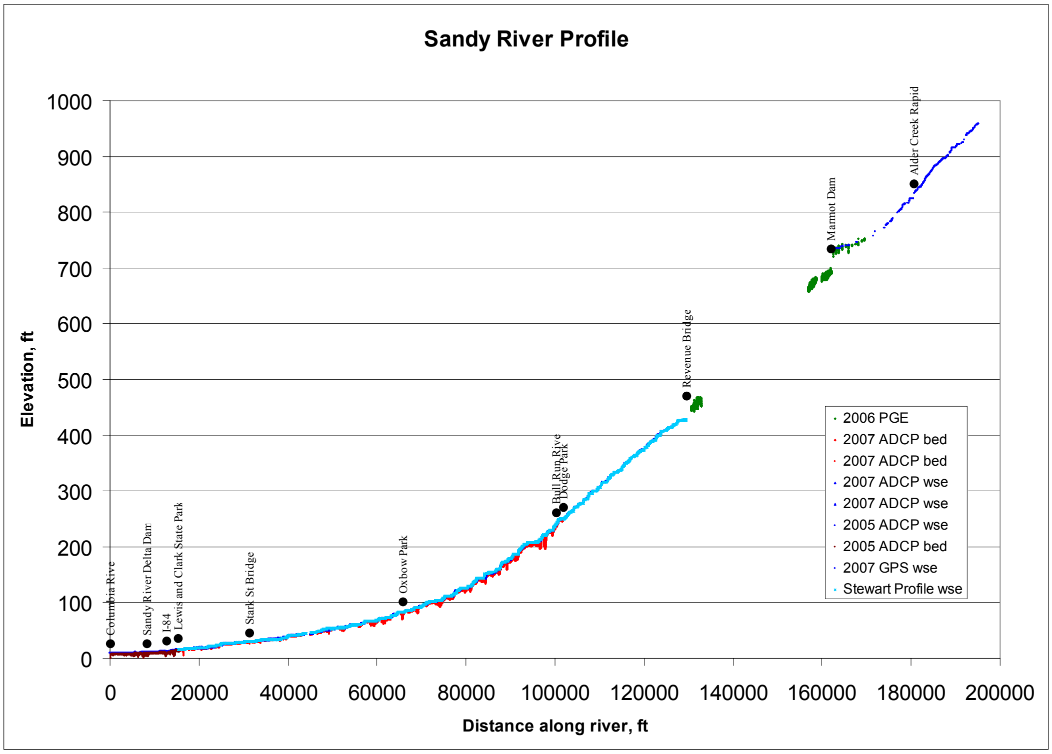

Figure 5 Long profile of the Sandy River from Brightwood to the Columbia River.

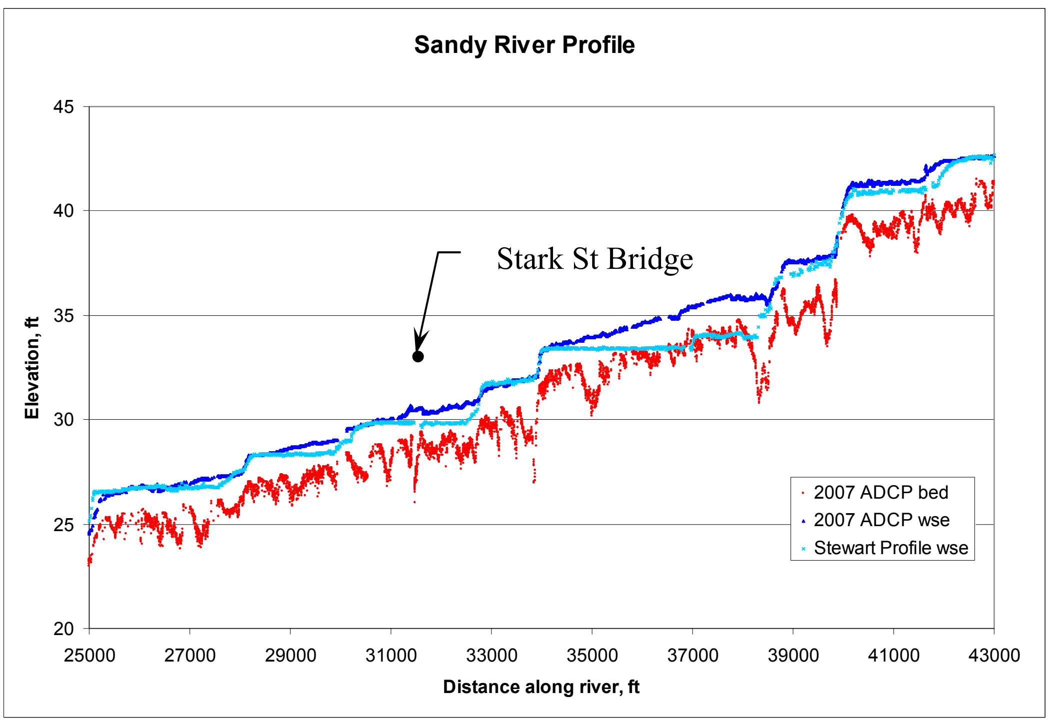

Figure 6 Comparison of 2004 and 2007 profiles in the Oxbow to Lewis and Clark reach.

Post-dam Removal

There have been several moderate high flows on the Sandy River since removal of Marmot Dam. During these flows a large amount of sediment has moved out of the former reservoir pool. Near the dam, the channel adjusted quickly. Immediately downstream from Marmot Dam the channel aggraded while bed elevations upstream from the dam decreased significantly. Figure 7 shows a comparison of water surface and bed elevation data taken before and after Marmot Dam was removed in fall 2007. Bed elevations in the upstream end of the reservoir have not decreased as much as downstream and there is a distinct slope break about one mile upstream from the dam near the power lines. Upstream from the slope break there has been minimal down-cutting and there is little separation between the normal reservoir pool line on the banks and the current water surface. Downstream from the slope break there is more separation between the normal pool elevation and the current water surface.

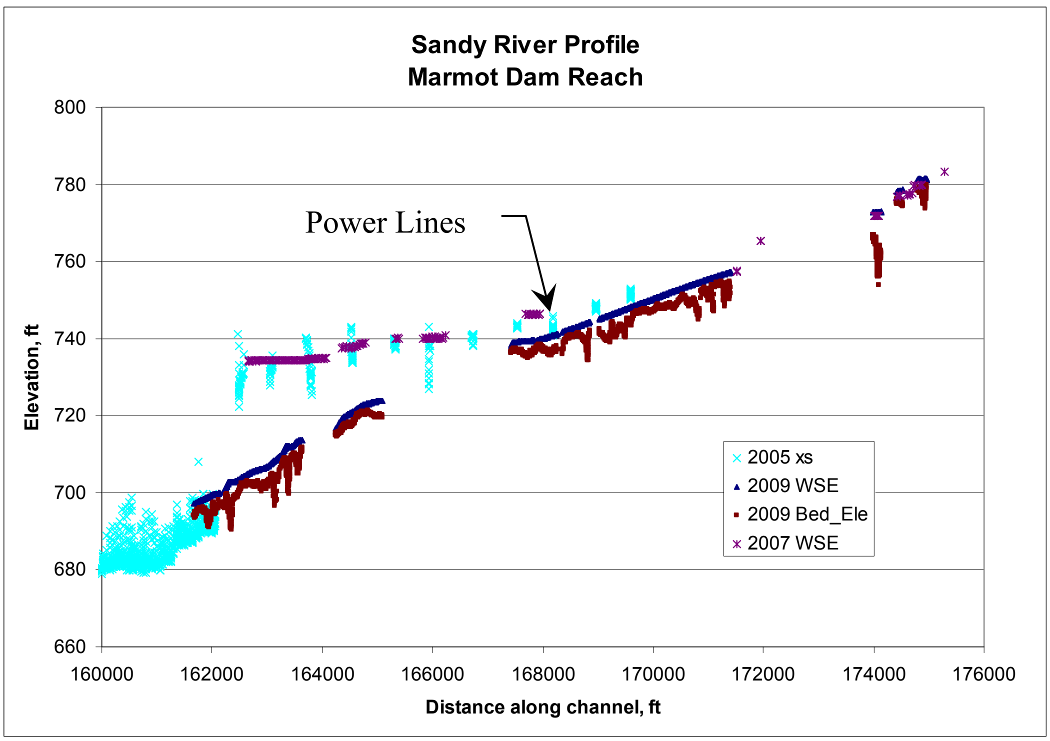

Figure 7 Comparison of channel profile near Marmot Dam before and after dam removal.

While there have been significant geomorphic changes to the Sandy River near Marmot Dam, the sediment wave propagating downstream has not made it through the Sandy Gorge or downstream from Revenue Bridge. Because of the equipment failure during the 2007 survey there are not multiple longitudinal profiles to compare between Revenue Bridge and Dodge Park. Visually, there have only been minor changes in this reach since Marmot Dam was removed. There are localized areas where pools are filling with sediment; however, this is most likely caused by bank erosion or mass wasting of high banks as seen in Figure 8.

Figure 8 Bank failure downstream from Revenue Bridge.

The Dodge Park to Oxbow reach does have multiple profiles that can be compared, but this reach is similar to the upstream reach in that there are no signs of sediment deposition that can be attributed to Marmot Dam. Profile comparison (Figure 9) shows very little change in bed elevation before and after dam removal. Areas with significantly different bed elevations in the two surveys are attributed to changes in boat path and not sediment deposition.

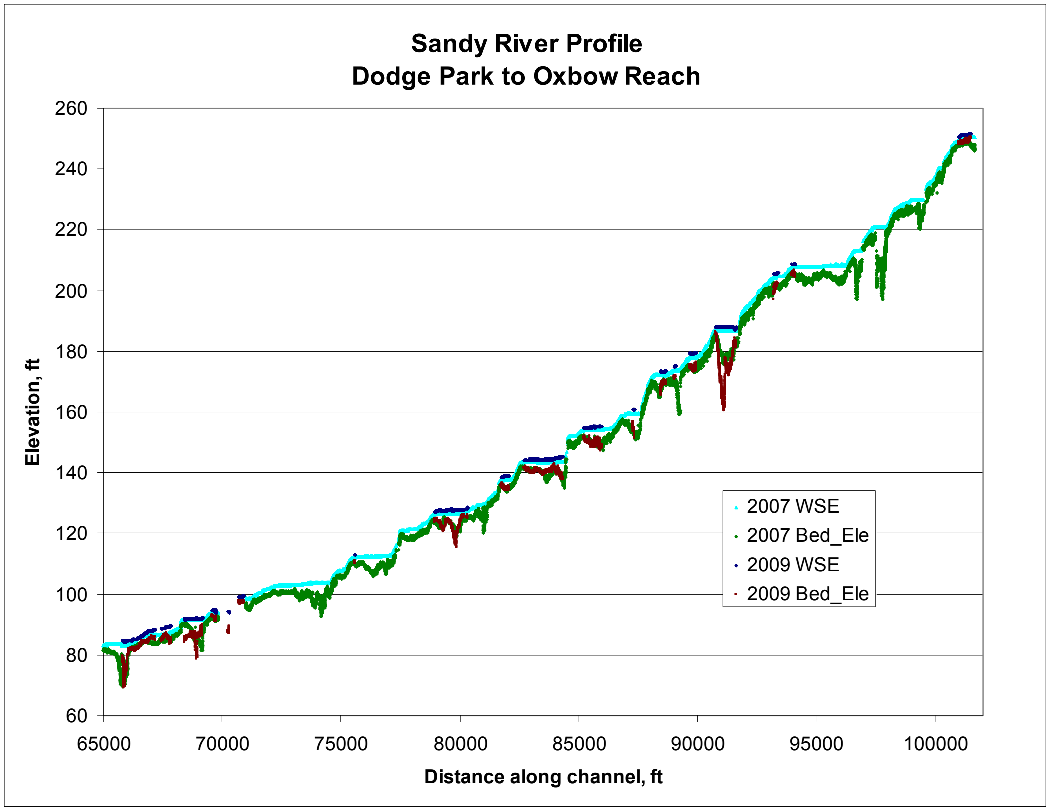

Figure 9 Comparison of channel profile between Dodge Park and Oxbow Park before and after dam removal.

Field Observations

General observations of river features made during the 2007 and 2009 surveys are summarized in this section. First, there is a distinct change in bank material composition that first appears near Oxbow Park. Upstream from this area the banks are mostly composed of bedrock with some terraces composed of cobbles and small boulders. Beginning a short distance upstream from the Oxbow Park boat ramp a buried terrace (Figure 10) with large trees appears along the active channel. The terrace is approximately 30 to 40 feet high and is primarily composed of sand. The river appears to be actively eroding many of these sand banks. Local accounts of the November 2006 flood suggest that the river has laterally migrated into many of these banks. Aerial photography that predates the 2007 survey supports this conclusion as the boat path from the surveys is sometimes in areas of dense vegetation that have been eroded. It is likely that the sand found in the pools downstream from Oxbow Park is from these sand banks and was not transported into the reach from further upstream.

Figure 10 Picture of tall sand bank with buried trees in the Oxbow reach.

Another observation that is worth noting is the location of the reservoir influence upstream from Marmot Dam. Near river station 173,000 there is a noticeable change in the composition of the rapids. Upstream from this point the rapids are composed of boulders or bedrock (Figure 11). Downstream from this point the rapids give way to riffles and there are no large boulders visible in the riffles. The drops become large piles of cobbles and small boulders. Alternating and mid-channel cobble bars also appear. It is likely that there are boulders here but they have been buried by reservoir sediments.

Even though there has been significant vertical change since Marmot Dam was removed, the riffle composition in the majority of the reservoir pool has remained unchanged. The riffles are still composed of mostly cobbles. Some bedrock and large boulders have been exposed in the reservoir pool but most of the riffles and riverbed are free from large boulders. Exposed bedrock currently has more affect on flow direction and is not significantly affecting the vertical stability of this reach as the river has not yet down-cut to boulders and bedrock that likely underlies the reservoir sediment deposits.

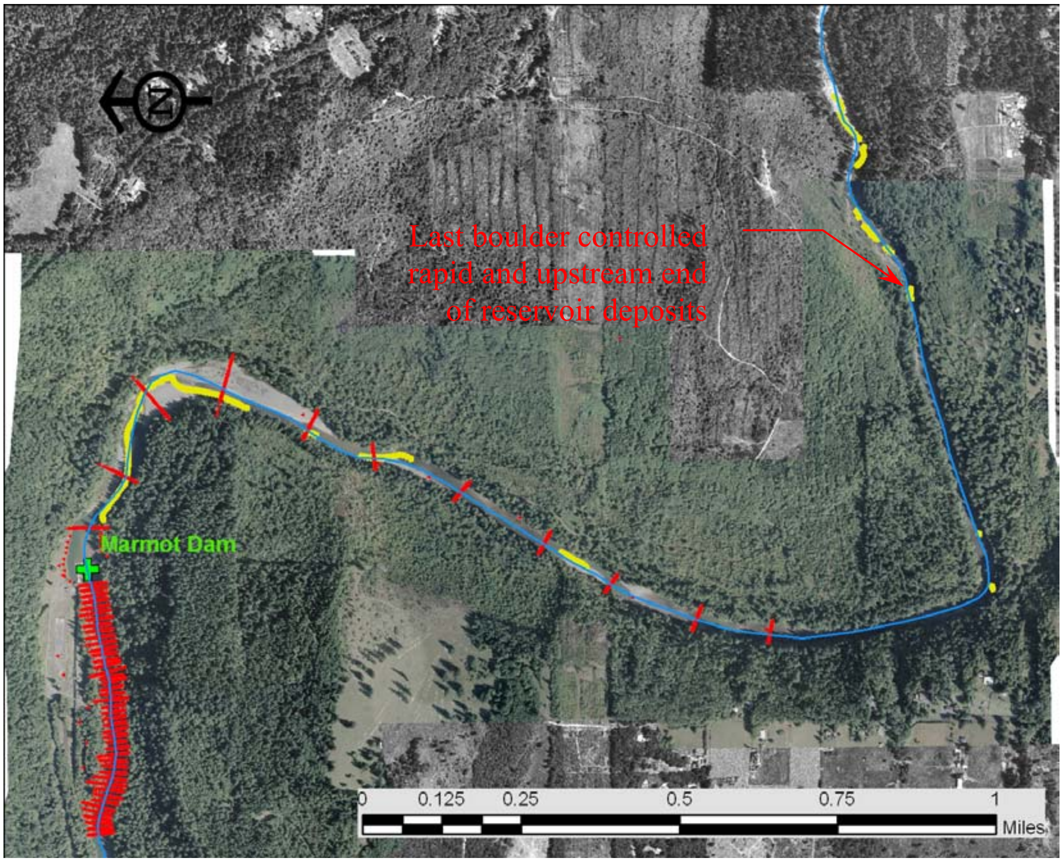

Figure 11 Extent of reservoir influence (Red lines indicate locations of cross sections surveyed in 2005 or 2006).

Conclusions and Recommendations

Water surface and bed profiles of the Sandy River were surveyed in 2007 and 2009 to monitor changes in channel elevation following the removal of Marmot Dam. Equipment failure and difficult site conditions limited the amount of data that were collected in some areas. Significant changes in bed elevation downstream from Revenue Bridge are not detectable at this time. Pool filling in these areas is likely caused by locally derived sediment. Changes in bed elevation have been more significant near Marmot Dam. The riverbed has aggraded downstream from the dam and significantly degraded upstream from the dam. Effects of this degradation extend approximately 1 mile upstream from the dam. Further upstream there has been minimal change in bed elevation and the slope remains similar to pre-dam removal conditions.

Further change in the reservoir pool will be limited by the ability of the channel to transport the large cobbles covering the riverbed. The river is capable of moving this material, but the transport rate is highly dependant on the magnitude of peak discharges. Unless there is a large magnitude flood it may take decades for the river to fully adjust to the dam removal and completely evacuate the reservoir sediment.

At this time, the river will continue to change as sediment is slowly transported out of the reservoir. The most significant changes will occur in the vicinity of Marmot Dam. Additional profile surveys will improve the understanding of the dam removal process and how long it actually takes for the river to adjust to large inputs of sediment. Future surveys can be limited to the reservoir pool and the area immediately downstream as these are the areas that will change the most. If the sediment wave does pass through the Sandy Gorge, surveys could be extended downstream. The frequency of the surveys can also be reduced. Major changes will be limited to large floods. Repeat surveys in the reservoir pool should be conducted every 5 to 10 years or following a major flood.

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